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Structure and organization of butterfly communities in a variety of woodlands at the northern foot of Mt Fuji, central Japan

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Abstract To clarify the structure and organization of butterfly communities, I analyzed a transect-count data set of seven butterfly communities in varying types of woodland habitat at the northern foot of Mt Fuji, central Japan. The results of statistical analyses including UPGMA suggested that the butterfly community was composed of four species subgroups that showed either relatively high abundances and wide local distributions (subgroup IV), relatively low abundances and wide local distributions (subgroups I and III), or relatively low abundances and restricted local distributions (subgroup II). The result of PCA suggested that the extent of growth in the mantle and sleeve plant communties (*i. e.* the degree of development of forest edges (corresponding to ecotone)) in each habitat played the major role in the diversification, formation, and organization of the four species subgroups. The two species subgroups IV and II, although quite different in abundance and distribution patterns, both had a great influence on the variations in the community indices such as species richness (total number of species) and total population abundance among the seven transect sites, whereas the other two subgroups I and III did not. From the analysis of the habitat types associated with the component species of the four species subgroups, it may be suggested that the differences in population abundances among the four species subgroups could be interpreted in terms of the sources and sinks theory (*e. g.* Pulliam, 1988). Overall, my analysis demonstrates that statistical approaches, including multivariate analysis, are very effective in the analysis of the structure and organization of butterfly communities.

Key words Butterfly communities, community structure, species composition, woodland habitat, forest edge.

Introduction

Up to the present, there have been many studies on the diversity, structure, and composition of butterfly communities (see Gilbert & Singer, 1975; Gilbert, 1984; Yamamoto, 1988; Porter *et al.*, 1992; Ishii, 1993; Pollard & Yates, 1993; New, 1997; Imai & Ishii, 1998). In these studies, butterfly communities have often been analyzed from the viewpoint of community parameters such as species richness, species diversity, equitability, total population abundance, etc. (see New, 1997; Natuhara, 1998; Sakuratani, 1998) and 'environmental indices' (*e. g.* Tanaka, 1988; Sunose, 1993, 1996, 1998; Hattori *et al.*, 1997; Tashita & Ichimura, 1997). However, especially in Japan, few attempts have been made to analyze butterfly community structure using a multivariate statistical approach, except by Fujii (1988), Yamamoto (1991*a*, 1991*b*, 1993, 1996) and Natuhara (1996). In addition, there have been few studies that have tried to determine the organizing force of butterfly communities using statistical approaches.

In my previous study (Kitahara, 1999), I monitored seven butterfly communities in varying types of woodland habitat by the line transect method during 1996 at the northern foot of Mt Fuji, central Japan. In this study, I used the butterfly community data set stated above, and analyzed the structure and organization of the communities using a multivariate statistical

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approach. My goals of this study were 1) to discriminate the species subgroups which constituted the butterfly community, 2) to identify the environmental factors contributing to the diversification and formation of the species subgroups of the community (if they are discovered), and 3) to clarify the characteristics and role in a community of the species subgroups (if they are discovered).

Materials and methods

Data set analyzed

In this paper, I used the data collected in my previous study; because details of the census sites are described elsewhere (Kitahara, in press), only short descriptions follow. I established seven butterfly transects in different woodland types (alt. *ca* 1,000 m) at the northern foot of Mt Fuji (alt. 3,776 m), Yamanashi Prefecture, central Japan. The two sites at Tsuchimarubi were located along the outer (site 1) and inner (site 2) forest edges of broad-leaved deciduous plantations that were sunny and relatively undisturbed. The Nakanochaya site was the most shady transect, located in a coniferous and deciduous mixed forest. The Hokuroku-Park site was in an area of naturally remaining and artificially transplanted woods with human-managed undergrowth. The Kankyouken site was in a recently logged and highly disturbed area surrounded by a secondary red pine forest. The two sites at Funatsutainai were located along the outer (site 1) and inner (site 2) forest edges of coniferous plantations that were sunny and relatively undisturbed. Table 1 summarizes the characteristics of the seven transect sites.

I monitored butterfly communities along each transect twice a month during the adult flight season (from April to November, 1996) by transect counts (Pollard, 1977; Yamamoto, 1988; Ishii, 1993; Pollard and Yates, 1993). Details of the census method are described elsewhere (Kitahara, 1999). I observed a total of 72 butterfly species along the seven transects. *Pieris melete* and *Pieris napi* were treated as a single species (*Pieris* sp.) because of the difficulty in distinguishing them in field censuses, especially during flight.

Data analysis

I analyzed butterfly community structure based on the population abundance of each species along each transect. Population abundance of each species was expressed as the mean monthly density for each transect, which was obtained by averaging the monthly densities, only when butterfly species were found. The monthly density was usually the mean of the two observations in each month. Exclusion of months when no butterflies were observed minimized the effect of variations in the voltinism of butterfly species on the yearly abundance estimate (*i. e.* the mean monthly density). Average population abundance of each component species in the community was calculated by averaging the population abundances of each transect, only where butterfly species were recorded, and converting this value into that per 1 km. Exclusion of transects where no butterflies were recorded minimized the effect of different distribution patterns (widespread or restricted) of butterfly species on the average population abundance. All butterfly species observed, the population abundance of each species at each transect, and the average population abundance of each species in the entire butterfly community are described in the Appendix.

A 72 (species) by 7 (transect sites) matrix based on the population abundance (mean monthly density) of each species at each transect was subjected to multivariate analyses. Species composition and clustering were examined by cluster analysis (unweighted pair-group method using arithmetic average (UPGMA)) based on a 72 by 72 Euclidean distances matrix.

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Table 1. Summary description of the seven study sites.

Study site	Tsuchimarubi 1	Tsuchimarubi 2	Nakanochyaya
Altitude	920–940 m	920–940 m	1,050–1,075 m
Vegetation			
High tree layer			*Pinus densiflora* & *Larix leptolepis* plantation
Subhigh tree layer	*Alnus hirsuta* plantation	*Alnus hirsuta* plantation	Broad-leaved deciduous trees
Degree of growth of mantle community	Intermediate	High	Intermediate
Degree of growth of sleeve community	High	High	Low
Sunlight condition (forest edge)	More bright	Bright	Highly dark
Level of human disturbance (forest edge)	Intermediate	Low	Low

Hokuroku park	Kankyoken	Funatsutainai 1	Funatsutainai 2
1,010–1,030 m	1,030–1,050 m	1,050–1,060 m	1,050–1,070 m
Remaining or transplanted trees	*Pinus densiflora* secondary forest	*Pinus densiflora* & *Larix leptolepis* plantation	*Pinus densiflora* & *Larix leptolepis* plantation
Remaining or transplanted trees	Broad-leaved deciduous trees	Broad-leaved deciduous trees	Broad-leaved deciduous trees
Low	Very low	High	High
Low	Very low	Very high	High
Bright	Bright	Bright	Bright
Very high	Very high	Intermediate	Low

Species ordination was carried out by principal components analysis (PCA) based on a variance-covariance matrix. Characteristics of the species groups or clusters found through multivariate approaches were examined in relation to biological attributes of the component species. Those used in the analyses were 1) voltinism (based on Unno and Aoyama (1981), and also on the actual data of seasonal changes in the observed number of individuals of each species in my study), 2) larval diet breadth (based on Endo and Nihira (1990)), 3) overwintering stage (based on Unno and Aoyama (1981)), and 4) habitat type (based on Miyatake (1998)).

Results

Species composition and grouping by cluster analysis (UPGMA)

Figure 1 shows the community dendrogram of Euclidean distances between all butterfly species. When the level of the Euclidean distance for the division of samples was determined arbitrarily to be 2.55, there were four major clusters (species subgroups) (I, II, III, and other

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species (IV)). The mean values of average population abundance of component species among the four species subgroups were significantly different (ANOVA: $F=29.271$, $P<0.01$) (Fig. 2a). In addition, the mean values for the numbers of transect sites where each component species was observed were also significantly different among the four species subgroups (ANOVA: $F=23.768$, $P<0.01$) (Fig. 2b).

These results implies that the butterfly community was composed of the following 4 species subgroups with different densities and/or distributions: 1) a species subgroup with high abundances and wide distributions (IV), 2) that with low abundances and wide distributions (I and III), and 3) that with low abundances and narrow distributions (II).

Species ordination by PCA

Distribution of the butterfly species observed on major (the first)- and minor (the second)-axes plane by PCA based on a variance-covariance matrix is shown in Fig. 3. The species subgroups (I, II, III and IV) detected by cluster analysis distributed from left to right sides along the major axis. The tightly packed species subgroup II distributed mainly on the left side of the major axis. On the contrary, the scattered species subgroup IV distributed mainly on the right side of the axis. The other two subgroups I and III were almost situated between subgroups II and IV along the major axis. These PCA results support the validity of the species grouping and clustering detected by UPGMA stated above.

The cumulative contribution of the first and second principal components was 74.05% (Table 2). For the first axis, the values of eigenvectors were all positive. The Funatsutainai sites 1 and 2, where more growth mantle and sleeve plant communities were featured (Table 1), had the highest eigenvector values (>0.5), while the Kankyouken site, which was an area with almost no mantle and sleeve plant communities (because it was recently logged and highly disturbed by humans) (Table 1), had the lowest eigenvector value (0.07). The degree of growth in the mantle and sleeve communities in the other four transect sites was almost intermediate between the Funatsutainai two sites and the Kankyouken site. These results suggest that the first axis reflected a gradient of the extent of growth in the mantle and sleeve plant communities of the sites.

Table 2. Eigenvalues and eigenvectors of the variance-covariance matrix used for PCA of the butterfly community.

		Principal components	
		Axis 1	Axis 2
Eigenvalue		52.2230	12.7664
Contribution to community variance (%)		59.50	14.55
Cumulative %		59.50	74.05
Eigenvector	Tsuchimarubi 1	0.2727	0.1443
	Tsuchimarubi 2	0.3917	0.7331
	Nakanochaya	0.2778	−0.5527
	Hokuroku-Park	0.2259	−0.0389
	Kankyoken	0.0725	−0.0730
	Funatsutainai 1	0.5882	0.0567
	Funatsutainai 2	0.5411	−0.3552

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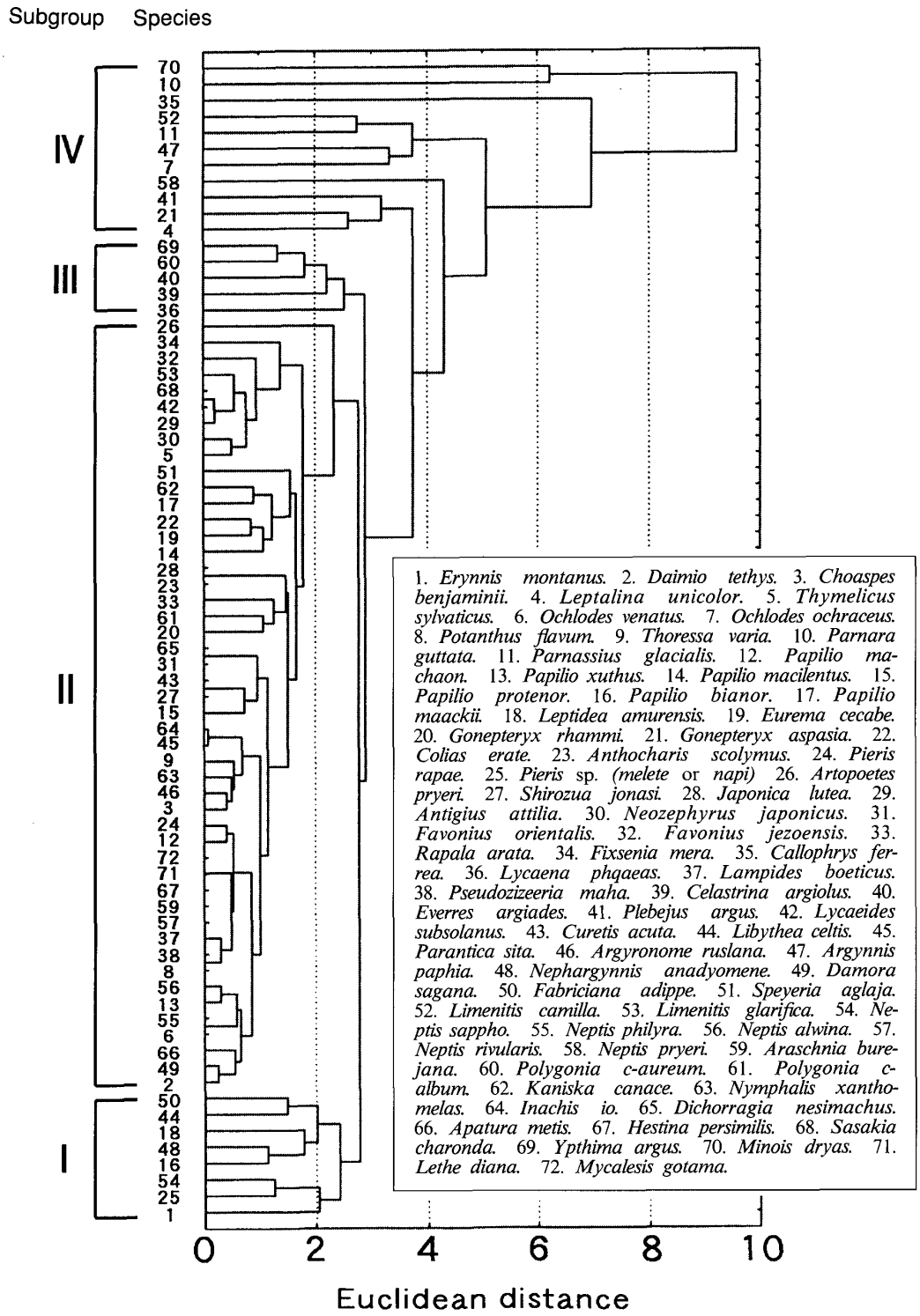

Fig. 1. Dendrogram of 72 butterfly species classified by the cluster analysis (unweighted pair-group method using arithmetic average (UPGMA)) based on a 72 by 72 Euclidean distance matrix. The species numbers in the figure correspond to those in Appendix.

For the second axis, the first and second highest eigenvector values were detected in Tsuchimarubi sites 2 and 1, which were located in the inner and outer areas of a broad-leaved deciduous forest, respectively (Table 1). On the other hand, the first and second lowest values were found in the Nakanochaya site and the Funatsutainai site 2, which were located

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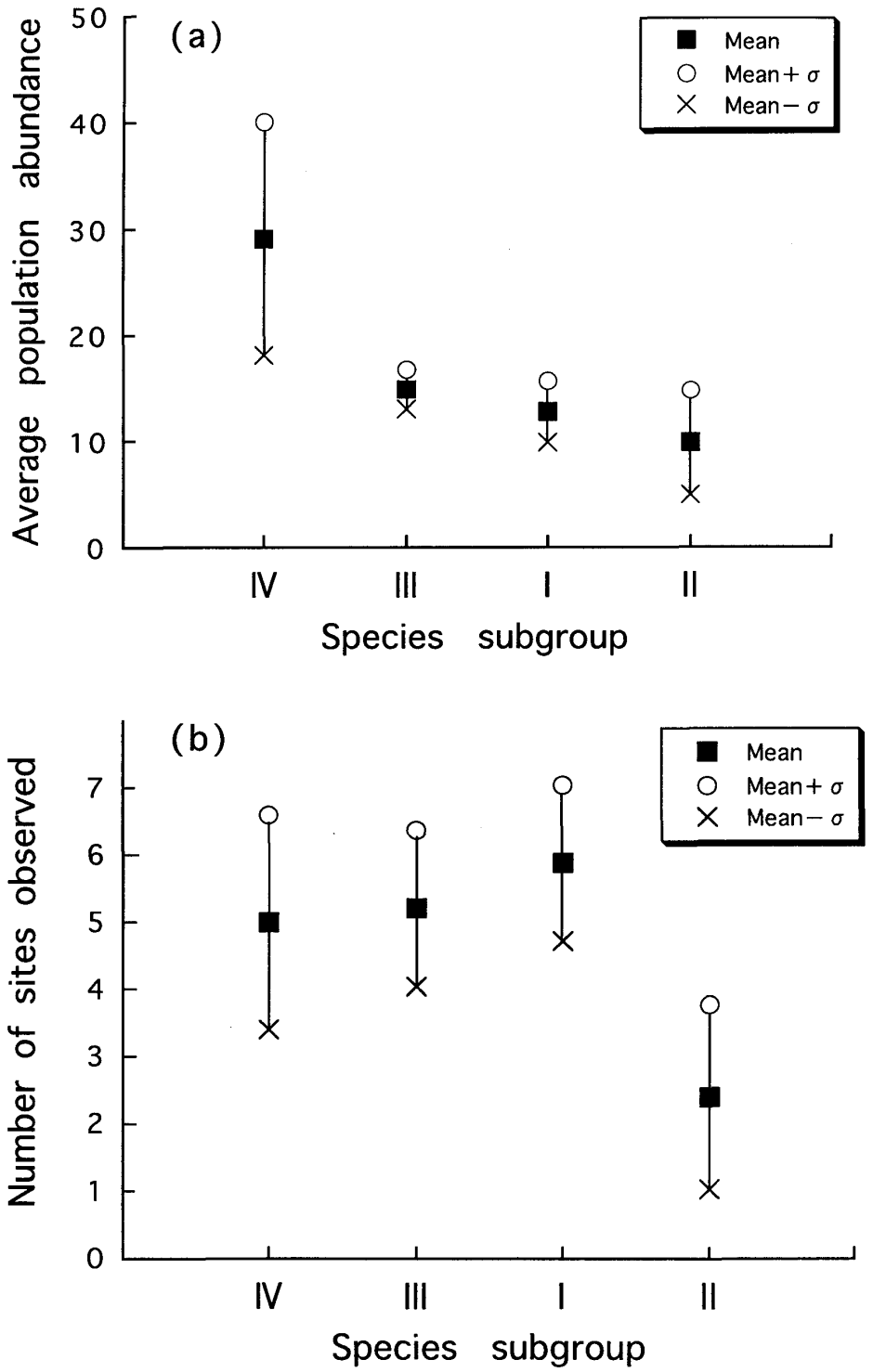

Fig. 2. Differences in the average population abundance (a) and the number of census sites observed (b) among the four species subgroups of the butterfly community.

in the inner and outer areas of a conifer-dominated forest, respectively (Table 1). These results suggest that the second axis reflects a gradient from broad-leaved deciduous woods via the ecotonal areas of woods to conifer-dominated woods.

The results of PCA indicate that the species grouping and clustering by UPGMA are

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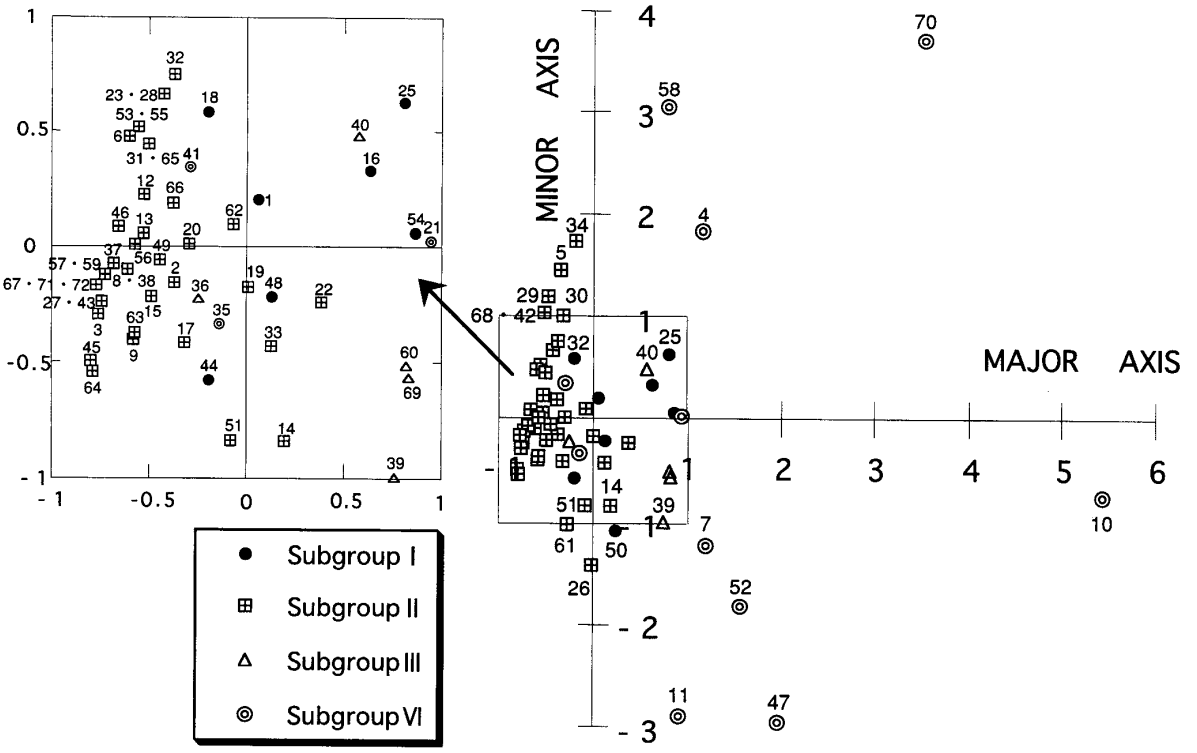

Fig. 3. Scattergram of 72 butterfly species along the first and the second principal component axis based on PCA ordination. The species numbers in the figure correspond to those in Fig. 1 and Appendix.

governed by the first axis (the extent of growth in the mantle and sleeve plant communities of the sites).

Correlations between butterfly species richness and abundance in each transect site, and the number of species in each subgroup in each transect site

Butterfly species richness (the total number of species in each transect site) was significantly and positively correlated with the number of species in subgroups II and IV in each transect site (II: $r=0.988$, $P<0.01$; IV: $r=0.881$, $P<0.01$), but not with that in subgroups I and III (I: $r=0.003$, $P>0.05$; III: $r=0.735$, $P>0.05$) (Fig. 4a). In addition, butterfly species abundance (the total population abundance of all species observed in each transect site) was significantly and positively correlated with the number of species in subgroups II and IV in each transect site (II: $r=0.894$, $P<0.01$; IV: $r=0.963$, $P<0.01$), but not with that in subgroups I and III (I: $r=-0.372$, $P>0.05$; III: $r=0.615$, $P>0.05$) (Fig. 4b).

Comparisons of various characteristics among the four butterfly subgroups

Table 3 shows the comparisons of various ecological characteristics cited from the literature among the 4 butterfly subgroups detected in the previous analyses. As for the voltinism of the component species, subgroup III was composed completely of multivoltine species. In contrast, subgroup IV was composed mostly (81.8%) of univoltine species. The other two subgroups I and II were composed of multi- and univoltine species in similar proportions (about 50.0% each). There were no marked differences in the overwintering stage of component species among the four subgroups; the highest values for the overwintering stage was obtained in the larval stage for all subgroups I (43.8%), II (37.5%), III (60.0%), and IV

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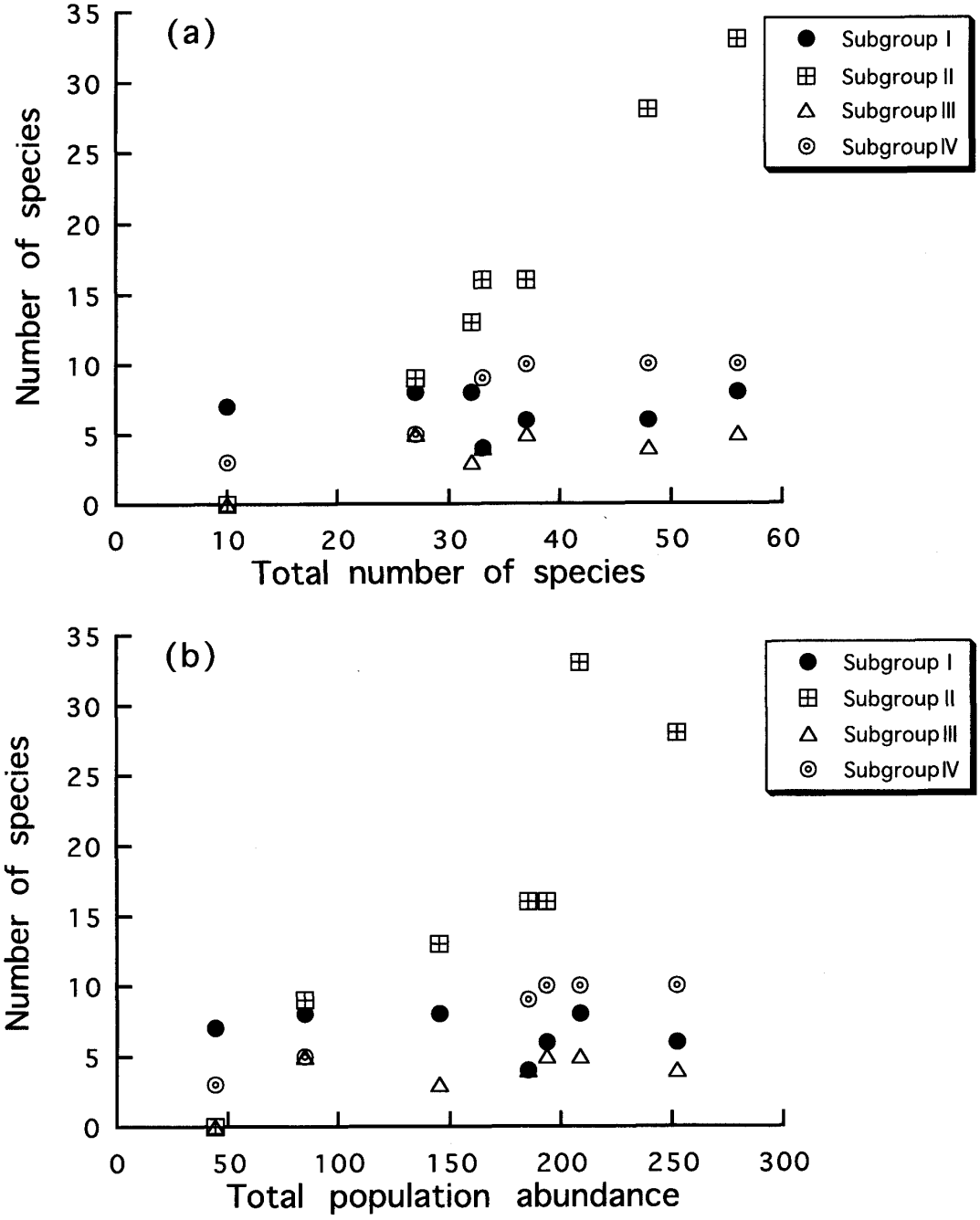

Fig. 4. Relationships of the number of species in each subgroup with species richness (the total number of species) (a), and with total population abundance (b).

(59.1%).

Among the categories of habitat type as appearing in Table 3, the habitat type usually occurring in the present study area is considered to be broad-leaved deciduous warm-temperate forest, broad-leaved deciduous cold-temperate forest, dry-type grassland, and sparse woods (marked by ** in Table 3). When we note the total proportion of the habitat types occurring in the present study area as stated above (see Table 3), 81.6% of well-known habitat types associated with subgroup IV as cited from the literature corresponded to the habitat types occurring in the present study area, whereas the well-known habitat types associated

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Table 3. Comparisons of various characteristics cited from the literature among the four species subgroups of the butterfiy community.

Characteristics	Species subgroup I No. spp.	(%)	II No. spp.	(%)	III No. spp.	(%)	IV No. spp.	(%)
Voltinism & larval diet breadth*								
Multivoltine & generalist	2	(25.0)	9	(18.8)	1	(20.0)	1	(9.1)
Multivoltine & specialist	2	(25.0)	14	(29.2)	4	(80.0)	1	(9.1)
Univoltine & generalist	0	(0.0)	6	(12.5)	0	(0.0)	4	(36.4)
Univoltine & specialist	4	(50.0)	19	(39.6)	0	(0.0)	5	(45.5)
Overwintering stage								
Egg	0.5	(6.3)	11	(22.9)	0	(0.0)	2.5	(22.7)
Larva	3.5	(43.8)	18	(37.5)	3	(60.0)	6.5	(59.1)
Pupa	3	(37.5)	11	(22.9)	1	(20.0)	1	(9.1)
Adult	1	(12.5)	7	(14.6)	1	(20.0)	1	(9.1)
Unknown	0	(0.0)	1	(2.1)	0	(0.0)	0	(0.0)
Habitat type								
Broad-leaved evergreen forest	2.5	(31.3)	7	(14.6)	1	(20.0)	0.5	(4.6)
Broad-leaved deciduous warm-temperate forest**	2	(25.0)	7.3	(15.3)	0	(0.0)	3	(27.3)
Broad-leaved deciduous cold-temperate forest**	0	(0.0)	4.3	(9.0)	0	(0.0)	1.5	(13.6)
Upper river basin	1	(12.5)	6	(12.5)	0	(0.0)	0	(0.0)
Lower or middle river basin	0.5	(6.3)	3.3	(6.9)	2	(40.0)	0.5	(4.6)
Dry-type grassland**	2	(25.0)	5.5	(11.5)	1.5	(30.0)	4	(36.4)
Wet-type grassland	0	(0.0)	1.5	(3.1)	0	(0.0)	0	(0.0)
Sparse wood**	0	(0.0)	3.5	(7.3)	0	(0.0)	0.5	(4.6)
Arable field	0	(0.0)	6	(12.5)	0.5	(10.0)	0.5	(4.6)
Residential and urban area	0	(0.0)	1	(2.1)	0	(0.0)	0.5	(4.6)
Others	0	(0.0)	2.5	(5.2)	0	(0.0)	0	(0.0)
Total proportion of habitat types occurring in the study area (marked by**)		(50.0%)		(43.0%)		(30.0%)		(81.6%)
Total proportion of habitat types rarely occurring in the study area		(50.0%)		(57.0%)		(70.0%)		(18.4%)

* Larval diet breadth: specialist; the species whose larvae had been reported to feed on hostplants belonging to one taxonomic family, generalist; the species whose larvae had been reported to feed on hostplants belonging to two or more taxonomic families.

**: the habitat type occurring in the study area.

with subgroup III such as lower and middle river basin and arable fields rarely occurred in the present study area (only 30.0% occurred). For the other subgroups I and II, about half of the known habitat types cited from the literature occurred regularly in the study area, while the other half such as broad-leaved evergreen forest and upper river basin did not.

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Discussion

Species composition of the butterfly community

Results of the cluster analysis (UPGMA) and ANOVAs of average population abundances and local distribution patterns of component species suggested that the butterfly community was composed of four species subgroups. These subgroups were classified into three types: 1) that with high abundances and wide distributions (one subgroup), 2) that with low abundances and wide distributions (two subgroups), and 3) that with low abundances and narrow distributions (one subgroup). In addition, the results of PCA also roughly supported the species grouping and clustering generated by UPGMA. The 4 species subgroups discriminated by UPGMA were arranged almost independent of each other along the first axis of the PCA. This suggests that the extent of growth in the mantle and sleeve plant communties (*i. e.* the degree of development of forest edges (corresponding to ecotones)), which related to the first axis of the PCA, played the central role in the diversification, formation, and organization of the species subgroups of the butterfly community.

Up to the present, it has been generally thought that the development of ecotones (forest edges in woodlands) enhances species diversity and richness in communities (*e. g.* Pianka, 1988; Smith, 1990; Ishii *et al.*, 1995; Ishii, 1996; Maeda, 1996; Natuhara, 1996; Tanaka & Arita, 1996; Yata, 1996). This is because such ecotonal communities include various characteristic types of species as a result of a variety of adjacent habitat components (Pianka, 1988; Smith, 1990; Yamamoto, 1993; Maeda, 1996). For butterflies, it has been pointed out that increases in resources such as nectar plants for adults and hostplants for larvae, based on the development of ecotones, enhances species diversity and richness in ecotonal butterfly communities (Ishii *et al.*, 1995, Ishii, 1996; Kitahara, unpublished). In addition to these mechanisms, my analysis demonstrates that the growth of mantle and sleeve plant communties, based on the development of forest edges, promotes the diversification and formation of species groups in butterfly communities, and as a result, enhances the diversity and species richness of ecotonal butterfly communities. This mechanism has received little attention so far. In general, it is considered that the growth of mantle and sleeve plant communities is governed mainly by physical disturbance and stress (*e. g.* Grime, 1977; Southwood, 1988). Therefore, it is thought that the physical conditions of disturbance and stress also govern the diversity and species richness of butterfly communities. Indeed, many studies have shown that butterfly species diversity is largely influenced by the degree of disturbance (*e. g.* Spitzer *et al.*, 1993, 1997; Kitahara & Fujii, 1994; Blair & Launer, 1997), and of stress (sunlight condition) (*e. g.* Warren, 1985; Greatorex-Davies *et al.*, 1993; Sparks *et al.*, 1996).

On the other hand, my analysis showed that the differences in the component tree species of woodlands, reflecting the second axis of PCA, played little role in the diversification and formation of the species subgroups of the butterfly community. In birds, it is well known that species diversity is more affected by foliage height diversity (indicating the extent of the development of stratification) than plant species diversity (*e. g.* MacArthur & MacArthur, 1961; MacArthur *et al.*, 1966; Cody, 1970; Karr, 1971; Higuchi,1978). Butterflies, on the other hand, in both the adult and larval stages depend mostly on plants as their necessary resource, and therefore, butterfly species diversity is generally thought to be strongly influenced by plant species diversity (as suggested by Katano (1995) and Ishii (1996)). My analysis, however, showed that the diversification and formation of species subgroups in the butterfly community, which contributed to the enhancement of species diversity, was promoted by the development of forest edge plant communties rather than the distinction of forest

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component tree species. The fact that this phenomenon was found in herbivorous insects such as butterflies is important. Probably, this is due to the high dependence of the nectar plants and hostplants of butterflies on the sleeve and mantle communities in forest edges. Similar arguments have been made by Ishii *et al.* (1995).

Consequently, the butterfly community was found to be composed of several species subgroups with different characteristics, and it was concluded that the degree of development in the habitat structure of forest edges may play an important role in the diversification and formation of species subgroups.

Characteristics of the species subgroups of the butterfly community

Table 4 summarizes the characteristics of the four species subgroups of the butterfly community based on the analyses of this study. As discussed above, it is suggested that these subgroups diverged along a gradient of the degree of development of forest edge sleeve and mantle plant communties. The species subgroup IV at one end of the gradient was associated with highly developed forest edge plant communities, and had large population sizes and wide local distributions. In contrast, subgroup II at the other end of the gradient was probably associated with components other than forest edge communities such as forest, grass, arable fields, and urban areas, and had small population sizes and restricted local distributions. The other two subgroups I and III were positioned between the two subgroups stated above along the gradient, and had intermediate features (small population sizes and wide distributions).

Table 4. Summary of the characteristics of the four species subgroups found in the butterfly community at the northen foot of Mt Fuji, central Japan.

Characteristics	Species subgroup			
	I	II	III	IV
Population density	Low	Low	Low	High
Local distribution pattern	Wide	Narrow	Wide	Wide
PCA I (The degree of development of mantle and sleeve communities)[1)]	Intermediate	Low	Intermediate	High
PCA II (Broad-leaved wood- coniferous wood gradient)[2)]	Broad-leaved[3)] Coniferous	Broad-leaved[3)] Coniferous	Broad-leaved[3)] Coniferous	Broad-leaved[3)] Coniferous
Correlation of the no. of spp. in each group[4)]				
with species richness	NS	++	NS	++
with total population abundance	NS	++	NS	++
Voltinism[5)]	−	−	M	(U)
Occurrence rate of the main habitats of each species subgroup in the study area	50.0%	43.0%	30.0%	81.6%

1) First principal component.
2) Second principal component.
3) Subgroup included both broad-leaved and coniferous woody areas depended species.
4) NS: not significant, ++: $P<0.01$
5) M: All species were multivoltine, (U): Most species were univoltine. −: No trends were detected.

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According to the results of the correlation analysis between butterfly species richness and abundance in each transect site, and the number of species in each subgroup in each transect site, only the number of species in subgroups II and IV were significantly and positively correlated with butterfly species richness (total number of species) and abundance (total population abundance of all species) in each transect site. This reflects the increase in both butterfly species richness and abundance with an increase in the number of species in subgroups II and IV. The presence of two types of species groups, those contributing to and those irrelevant to community indices such as species richness and total population abundance in a butterfly community, has been reported elsewhere (*e. g.* Kitahara & Fujii, 1994). Moreover, it is noteworthy that the subgroups II and IV, with quite distinct features from each other, played the major roles in the determination of certain kinds of community indices of the butterfly community. Probably, this is due to the results which show that the differences in habitat structure among the study sites highly reflected both the differences in forest edge habitat structure and those in non-forest edge habitat structure such as woodlands, grasslands, and plain fields among the study sites. The Tsuchimarubi sites, which showed the greatest species-richness and population-abundance in this study, are thought to have provided suitable habitat structure for many butterfly species of the subgroups IV , associated with developed forest edges, and II, more associated with non-forest edge components such as forest, grass, and plain fields. This is consistent with the arguments that greater species richness in forest edges is a result of the presence of various types of species groups characteristic to forest edge and characteristic to the neighboring habitats such as woodlands, grasslands, and plain fields (Pianka, 1988; Smith, 1990; Maeda, 1996).

The main habitat types of butterflies usually occurring in the study area were more consistent with those of the subgroup IV based on the literature than those of the other 3 subgroups. This means that, for most species of subgroup IV, the present study area may have been located near the center of their geographic ranges (*i. e.* the source area). On the other hand, there is a possibility that, for most of the species in the other 3 subgroups, the present area corresponded to the periphery of their ranges (*i. e.* near the sink area). Usually, it is thought that source populations in source habitats produce an excess of individuals (population growth rate: $r>0$), whereas sink populations in sink habitats have less local productivity than local mortality ($r<0$) (*e. g.* Pulliam, 1988; Lawton *et al.*, 1994; Lawton, 1995; Pulliam & Dunning, 1997). In addition, the intrinsic rate of natural increase (r) is usually proportional to population abundance. Thus, the differences in the average population abundance among the 4 species subgroups were probably due to differences in the population growth rate (r) depending on whether the individuals were part of source or sink populations. That is, the subgroup IV with high abundances may have been associated with a higher r because it was part of a source population, whereas the other 3 subgroups with low abundances may have been associated with a lower r because they were part of sink populations.

Consequently, in the butterfly community, there were different types of species subgroups, some of which played a great role in the determination of certain kinds of community indices, and the differences in the population abundances among the species subgroups may be interpreted in terms of the sources and sinks theory (*e. g.* Pulliam, 1988), as discussed above. Overall, my analysis demonstrates that statistical approaches, including multivariate analysis, is very effective in the analysis of the structure and organization of butterfly communities.

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References

Blair, R. B. and A. E. Launer, 1997. Butterfly diversity and human land use: species assemblages along an urban gradient. *Biol. Conserv.* **80**: 113–125.

Cody, M. L., 1970. Chilean bird distributions. *Ecology* **51**: 455–464

Endo, S. and I. Nihira, 1990. *Larval Food of Japanese Butterflies*. 74 pp, 20 pls. Group "Tamamushi", Tokyo. (In Japanese).

Fujii, K., 1988. [Statistical analysis of butterfly communities]. *In* Yonezawa, K., Sasaki, Y., Imanishi, S. and K. Fujii, [*Biostatistics*]: 163–170. Asakura, Tokyo. (In Japanese).

Gilbert, L. E., 1984. The biology of butterfly communities. *In* Vane-Wright, R. I. and P. R. Ackery (Eds), *The Biology of Butterflies*: 41–54. Academic Press, London.

Gilbert, L. E. and M. C. Singer, 1975. Butterfly ecology. *A. Rev. Ecol. Syst.* **6**: 365–397.

Greatorex-Davies, J. N., Sparks, T. H., Hall, M. L. and R. H. Marrs, 1993. The influence of shade on butterflies in rides of coniferised lowland woods in southern England and implications for conservation management. *Biol. Conserv.* **63**: 31–41.

Grime, J. P., 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *Am. Nat.* **111**: 1169–1194.

Hattori, T., Yagura, Y., Takeda, Y. and H. Ishida, 1997. A method of evaluation of naturalness by means of butterfly assemblages. *Humans Nature* **8**: 41–52 (in Japanese with English abstract).

Higuchi, H., 1978. [*The Ecology and Evolution of Birds*]. 199 pp. Shisakusha Publishers, Tokyo. (In Japanese).

Imai, C. and M. Ishii (supervision), 1998. [*Research Method for Butterflies*]. [v], 289 pp. Bunkyo-shuppan Co., Osaka. (In Japanese).

Ishii, M., 1993. Transect counts of butterflies. *In* Yata, O. and K. Ueda (Eds), *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec. Issue) **2**: 91–101. The Lepidopterological Society of Japan, Osaka and The Nature Conservation Society of Japan, Tokyo. (In Japanese with English summary).

————, 1996. Species diversity of butterfly communities in different environment of forests in southern Osaka. In Tanaka, B., and Y. Arita (Eds), *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec. Issue) **4**: 63–75. The Lepidopterological Society of Japan, Osaka. (In Japanese with English summary).

Ishii, M., Hirowatari, T. and S. Fujiwara, 1995. Species diversity of butterfly communities in "Mt. Mikusa coppice for *Zephyrus*". *Jap. J. envir. Ent. Zool.* **7**: 134–146 (in Japanese with English summary).

Karr, J. R., 1971. Structure of avian communities in selected Panama and Illinois habitats. *Ecol. Monogr.* **41**: 207–233.

Katano, O., 1995. [*An Introduction to modern Animal Ecology*]. 240 pp. Chuo-Kouron Publishers, Tokyo. (In Japanese).

Kitahara, M., 1999. Species diversity of butterfly communities in a variety of woodlands at the northern foot of Mt. Fuji, central Japan. *Jap. J. envir. Ent. Zool.* **10**: 11–29 (in Japanese with English summary).

Kitahara, M. and K. Fujii, 1994. Biodiversity and community structure of temperate butterfly species within a gradient of human disturbance: an analysis based on the concept of generalist vs. specialist strategies. *Researches Popul. Ecol. Kyoto Univ.* **36**: 187–199.

Lawton, J. H., 1995. Population dynamic principles. *In* Lawton, J. H. and R. M. May (Eds), *Extinction Rates*: 147–163. Oxford University Press, Oxford.

NII-Electronic Library Service

The Lepidopterological Society of Japan

Lawton, J. H., Nee, S., Letcher, A. J. and P. H. Harvey, 1994. Animal distributions: patterns and processes. *In* Edwards, P. J., May, R. M. and N. R. Webb (Eds), *Large-Scale Ecology and Conservation Biology*: 41–58. Blackwell Scientific Publications, Oxford.

MacArthur, R. H. and J. W. MacArthur, 1961. On bird species diversity. *Ecology* **42**: 594–598.

MacArthur, R. H., Recher, H. and M. L. Cody, 1966. On the relation between habitat selection and species diversity. *Am. Nat.* **100**: 319–332.

Maeda, T., 1996. [The conservation of ecosystems]. *In* Higuchi, H. (Ed.), [*Conservation Biology*]: 71–102. University of Tokyo Press, Tokyo. (In Japanese).

Miyatake, Y., 1998. [Living environment]. *In* Imai, C. and M. Ishii (supervision), [*Research Method for Butterflies*]: 1–15. Bunkyo-shuppan Co., Osaka. (In Japanese).

Natuhara, Y., 1996. Analysis of butterfly assemblages. *Nature Insects* **31**(14): 18–24 (in Japanese).

————, 1998. [Methods of analysis using diversity index]. *In* Imai, C. and M. Ishii (supervision), [*Research Method for Butterflies*]: 69–91. Bunkyo-shuppan Co., Osaka. (In Japanese).

New, T. R., 1997. *Butterfly Conservation* (2nd Edn). 248 pp. Oxford University Press, Melbourne.

Pianka, E., 1988. *Evolutionary Ecology* (4th Edn). 468 pp. Harper & Row, New York.

Pollard, E., 1977. A method for assessing changes in the abundance of butterflies. *Biol. Conserv.* **12**: 115–134.

Pollard, E. and T. J. Yates, 1993. *Monitoring Butterflies for Ecology and Conservation*. 274 pp. Chapman & Hall, London.

Porter, K., Steel, C. A. and J. A. Thomas, 1992. Butterflies and communities. *In* Dennis, R. L. H. (Ed.), *The Ecology of Butterflies in Britain*: 139–177. Oxford Science Publications, Oxford.

Pulliam, H. R., 1988. Sources, sinks, and population regulation. *Am. Nat.* **132**: 652–661.

Pulliam, H. R. and J. B. Dunning, 1997. Demographic processes: population dynamics on heterogeneous landscapes. *In* Meffe, G. K., Carroll, C. R. and Contributors (Eds), *Principles of Conservation Biology*: 203–233. Sinauer Associates, Inc., Sunderland, Massachusetts.

Sakuratani, Y., 1998. [Application of butterflies to the evaluation and prediction of environmental change]. *In* Imai, C. and M. Ishii (supervision), [*Research Method for Butterflies*]: 92–110. Bunkyo-shuppan Co., Osaka. (In Japanese).

Smith, R. L., 1990. *Ecology and Field Biology* (4th Edn). 922 pp. Harper Collins Publishers, New York.

Southwood, T. R. E., 1988. Tactics, strategies and templets. *Oikos* **52**: 3–18.

Sparks, T. H., Greatorex-Davies, J. N., Mountford, J. O., Hall, M. L. and R. H. Marrs, 1996. The effects of shade on the plant communities of rides in plantation woodland and implications for butterfly conservation. *Forest Ecol. Mgmt* **80**: 197–207.

Spitzer, K., Jaros, J., Havelka, J. and J. Leps, 1997. Effect of small-scale disturbance on butterfly communities of an Indochinese montane rainforest. *Biol. Conserv.* **80**: 9–15.

Spitzer, K., Novotny, V., Tonner, M. and J. Leps, 1993. Habitat preferences, distribution and seasonality of the butterflies (Lepidoptera, Papilionoidea) in a montane tropical rain forest, Vietnam. *J. Biogeogr.* **20**: 109–121.

Sunose, T., 1993. On a reseach method for butterfly assemblages. *In* Yata, O. and K. Ueda (Eds), *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec. Issue) **2**: 83–90. The Lepidopterological Society of Japan, Osaka and The Nature Conservation Society of Japan, Tokyo. (In Japanese with English summary).

————, 1996. Environmental evaluation for butterfly assemblages. *In* Ae, S. A., Hirowatari, T., M. Ishii and L. P. Brower (Eds), *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec. Issue) **3**: 110–115. The Lepidopterological Society of Japan, Osaka.

————, 1998. [Methods of analysis using environmental indicators]. *In* Imai, C. and M. Ishii (supervision), [*Research Method for Butterflies*]: 59–69. Bunkyo-shuppan Co., Osaka. (In Japanese).

Tanaka, B., 1988. A method of environmental evaluation by means of faunal composition of butterflies. *Spec. Bull. lepid. Soc. Japan* **6**: 527–566 (in Japanese with English abstract).

Tanaka, B. and Y. Arita (Eds), 1996. *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec.) **4**. The Lepidopterological Society of Japan, Osaka. (In Japanese with English summary).

NII-Electronic Library Service

The Lepidopterological Society of Japan

Tashita, M. and T. Ichimura, 1997. Environmental evaluation by butterfly communities according to altitude in Nagano Prefecture. *Jap. J. envir. Ent. Zool.* **8**: 73-88 (in Japanese with English summary).

Unno, K. and J. Aoyama, 1981. [*The Butterflies of Japan*]. 190 pp. Shougakkan Publishers, Tokyo. (In Japanese).

Warren, M. S., 1985. The influence of shade on butterfly numbers in woodland rides, with special reference to the wood white, *Leptidea sinapis*. *Biol. Conserv.* **33**: 147-164.

Yamamoto, M., 1988. On the research method for butterfly assemblages. *Spec. Bull. lepid. Soc. Japan* **6**: 191-210 (in Japanese with English abstract).

————, 1991*a*. Community structure of butterflies observed in and near Ryugasaki, 1982, based upon their habitat preference. *J. Ryutsu-Keizai Univ.* **26**: 1-10 (in Japanese with English synopsis).

————, 1991*b*. Community structure of butterflies observed in and near Ryugasaki, 1983, based upon their habitat preference. *J. Ryutsu-Keizai Univ.* **26**: 41-53 (in Japanese with English synopsis).

————, 1993. Community structure of butterflies observed in and near Ryugasaki, 1984, based upon their habitat preference. *J. Ryutsu-Keizai Univ.* **27**(3): 34-47 (in Japanese with English synopsis).

————, 1996. Ten year change of butterfly fauna observed in and near Ryugasaki. *In Contributions in Celebration of the 30th Anniversary of Ryutsu-Keizai University*: 447-491. Ryutsu-Keizai University Press, Ibaraki. (In Japanese with English synopsis).

Yata, O., 1996. Butterfly community in laurel-leaved forest of Yamada Park, Kitakyushu. *In* Tanaka, B. and Y. Arita (Eds), *Decline and Conservation of Butterflies in Japan* (*Yadoriga*, spec. Issue) **4**: 49-56. The Lepidopterological Society of Japan, Osaka. (In Japanese with English summary).

摘　　要

富士山北麓の種々な森林環境におけるチョウ類群集の構造と組織 (北原正彦)

チョウ類群集の内部構造や構成を明らかにするために，富士山北麓標高 1,000 m 近傍の 7 つの環境タイプの異なる森林地帯で，1996 年にトランセクト・カウント法を用いて集積したチョウ類群集のデータを用いて，多変量解析を含む分析を行った．

群分析 (UPGMA) を含む統計解析により，このチョウ類群集は高密度・広地域分布 (IV 群)，低密度・広地域分布 (I および III 群)，低密度・狭地域分布 (II 群) の 4 つの種群より成り立っていることが示唆された．主成分分析 (PCA) の結果も上のグルーピングをほぼ支持しており，さらにこの 4 つの種群の分化および形成には，森林の林縁部 (ソデ・マント群落) (エコトーン) の発達の程度が大きく関与していることが示唆された．互いに最も異なる密度と分布様式を示した II 群と IV 群は，群集の全体属性である総種数と総個体数の決定に大きく影響を与えていた反面，I 群および III 群の種数はそれらとは無関係であった．各種群の構成種の生息場所選択の解析から，4 種群間の平均個体群密度の違いは，source と sink の理論 (Pulliam, 1988 など) を用いて説明可能なことが判った．

今回の解析は，チョウ類群集の構造や機構の解明に，多変量を含む統計解析が大変有効であることを示唆している．

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Appendix. Population abundance of each butterfiy species observed in the 7 woodland study sites at the northern foot of Mt. Fuji, from April to November in 1996. Actual annual counts for each species are shown in parentheses.

Sp. no.	Species	Tsuchimarubi 1		Tsuchimarubi 2		Nakanochaya		Hokuroku-park		Kankyoken		Funatsutainai 1		Funatsutainai 2		Average*	(total)	No. sites observed
	Hesperiidae																	
1.	*Erynnis montanus*	6.67	(4)	5.00	(3)	5.00	(5)	1.67	(1)	—	—	—	—	—	—	15.28	(13)	4
2.	*Daimio tethys*	1.67	(1)	2.78	(5)	1.67	(1)	—	—	—	—	—	—	2.78	(4)	7.41	(11)	4
3.	*Choaspes benjaminii*	—	—	—	—	—	—	—	—	—	—	1.67	(1)	—	—	5.56	(1)	1
4.	*Leptalina unicolor*	8.33	(10)	10.83	(13)	—	—	—	—	—	—	8.33	(5)	6.67	(2)	28.47	(30)	4
5.	*Thymelicus sylvaticus*	1.67	(1)	8.33	(5)	—	—	—	—	—	—	—	—	—	—	16.67	(6)	2
6.	*Ochlodes venatus*	1.67	(1)	3.33	(2)	—	—	—	—	—	—	—	—	—	—	8.33	(3)	2
7.	*Ochlodes ochraceus*	6.67	(8)	5.83	(7)	13.33	(12)	6.67	(4)	—	—	5.00	(3)	1.67	(1)	21.76	(35)	6
8.	*Potanthus flavus*	3.33	(2)	—	—	—	—	—	—	—	—	—	—	—	—	11.11	(2)	1
9.	*Thoressa varia*	—	—	—	—	1.11	(1)	—	—	—	—	3.33	(1)	—	—	7.41	(2)	2
10.	*Parnara guttata*	12.78	(23)	14.17	(17)	7.50	(9)	10.00	(6)	5.00	(3)	27.08	(63)	30.00	(33)	50.73	(154)	7
	Papilionidae																	
11.	*Parnassius glacialis*	—	—	1.67	(1)	13.33	(8)	—	—	—	—	7.50	(5)	9.17	(6)	26.39	(20)	4
12.	*Papilio machaon*	2.50	(3)	1.67	(2)	—	—	—	—	—	—	1.67	(1)	—	—	6.48	(6)	3
13.	*Papilio xuthus*	2.50	(3)	1.67	(2)	—	—	—	—	—	—	—	—	1.67	(1)	6.48	(6)	3
14.	*Papilio macilentus*	1.67	(2)	1.67	(2)	2.50	(3)	1.67	(1)	—	—	3.33	(1)	6.67	(2)	9.72	(11)	6
15.	*Papilio protenor*	—	—	1.67	(1)	—	—	1.67	(1)	—	—	—	—	2.78	(3)	6.79	(5)	3
16.	*Papilio bianor*	2.78	(5)	6.67	(4)	2.78	(5)	2.22	(4)	3.33	(1)	6.67	(2)	3.33	(3)	13.23	(24)	7
17.	*Papilio maackii*	1.67	(1)	—	—	—	—	—	—	—	—	3.33	(1)	3.33	(1)	9.26	(3)	3
	Pieridae																	
18.	*Leptidea amurensis*	3.33	(9)	5.00	(3)	1.11	(1)	2.50	(3)	1.67	(1)	2.72	(2)	—	—	9.07	(19)	6
19.	*Eurema hecabe*	2.78	(5)	1.67	(1)	—	—	1.67	(3)	—	—	3.33	(3)	4.58	(10)	9.35	(22)	5
20.	*Gonepteryx rhamni*	3.33	(4)	1.67	(1)	1.67	(1)	—	—	—	—	3.33	(1)	—	—	8.33	(7)	4
21.	*Gonepteryx aspasia*	11.25	(26)	6.33	(18)	6.67	(11)	—	—	—	—	3.33	(7)	5.56	(9)	22.09	(71)	5
22.	*Colias erate*	4.33	(13)	1.67	(2)	—	—	1.67	(1)	—	—	5.56	(6)	6.67	(4)	13.26	(26)	5
23.	*Anthocharis scolymus*	5.00	(3)	3.33	(2)	—	—	—	—	—	—	—	—	—	—	13.89	(5)	2
24.	*Pieris rapae*	2.50	(6)	—	—	—	—	—	—	—	—	1.67	(1)	—	—	6.94	(7)	2
25.	*Pieris melete or napi*	5.28	(19)	9.00	(27)	4.81	(11)	2.00	(6)	1.67	(2)	5.00	(13)	3.33	(6)	14.81	(84)	7
	Lycaenidae																	
26.	*Artopoetes pryeri*	1.67	(1)	—	—	2.22	(2)	—	—	—	—	—	—	10.00	(6)	15.43	(9)	3
27.	*Shirozua jonasi*	—	—	—	—	—	—	1.67	(1)	—	—	—	—	—	—	5.56	(1)	1
28.	*Japonica lutea*	5.00	(3)	3.33	(2)	—	—	—	—	—	—	—	—	—	—	13.89	(5)	2
29.	*Antigius attilia*	—	—	7.50	(9)	—	—	—	—	—	—	—	—	—	—	25.00	(9)	1
30.	*Neozephyrus japonicus*	1.67	(2)	7.50	(9)	1.67	(1)	—	—	—	—	—	—	—	—	12.04	(12)	3
31.	*Favonius orientalis*	1.67	(1)	3.33	(2)	—	—	1.67	(1)	—	—	—	—	—	—	7.41	(4)	3
32.	*Favonius jezoensis*	—	—	5.00	(3)	—	—	—	—	—	—	3.33	(1)	—	—	13.89	(4)	2
33.	*Rapala arata*	5.00	(3)	1.67	(1)	3.33	(4)	1.67	(1)	—	—	3.33	(1)	2.50	(2)	9.72	(12)	6
34.	*Fixsenia mera*	3.89	(7)	9.17	(11)	—	—	—	—	—	—	—	—	—	—	21.76	(18)	2
35.	*Callophrys ferrea*	1.67	(1)	3.33	(2)	1.67	(1)	—	—	13.33	(4)	1.67	(1)	—	—	14.44	(9)	5
36.	*Lycaena phlaeas*	1.67	(3)	—	—	—	—	5.00	(3)	—	—	3.33	(1)	—	—	11.11	(7)	3

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37.	*Lampides boeticus*	2.50	(3)	—	—	—	—	—	—	—	—	—	—	8.33	(3)	1
38.	*Pseudozizeeria maha*	3.33	(2)	—	—	—	—	—	—	—	—	—	—	11.11	(2)	1
39.	*Celastrina argiolus*	4.17	(8)	2.50	(3)	5.56	(8)	6.67	(5)	—	—	4.44	(5)	5.00	(4)	15.74	(33)	6
40.	*Everes argiades*	5.00	(15)	4.00	(12)	—	—	2.50	(3)	—	—	7.78	(10)	4.17	(4)	15.63	(44)	5
41.	*Plebejus argus*	10.83	(13)	—	—	—	—	—	—	—	—	—	—	—	—	36.11	(13)	1
42.	*Lycaeides subsolanus*	—	—	6.67	(4)	—	—	—	—	—	—	—	—	—	—	22.22	(4)	1
43.	*Curetis acuta*	—	—	—	—	—	—	1.67	(1)	—	—	—	—	—	—	5.56	(1)	1
	Libytheidae																	
44.	*Libythea celtis*	3.33	(4)	—	—	2.22	(2)	1.67	(1)	3.33	(1)	3.33	(2)	—	—	9.26	(10)	5
	Danaidae																	
45.	*Parantica sita*	—	—	—	—	1.39	(2)	—	—	—	—	—	—	—	—	4.63	(2)	1
	Nymphalidae																	
46.	*Argyronome ruslana*	—	—	1.67	(1)	—	—	—	—	—	—	1.67	(1)	—	—	5.56	(2)	2
47.	*Argynnis paphia*	4.44	(8)	4.17	(5)	15.00	(26)	5.83	(7)	4.17	(5)	7.78	(13)	11.67	(16)	25.26	(80)	7
48.	*Nephargynnis anadyomene*	1.67	(1)	3.33	(4)	1.67	(1)	1.67	(1)	3.33	(1)	3.89	(5)	3.33	(3)	8.99	(16)	7
49.	*Damora sagana*	1.67	(1)	2.78	(5)	1.67	(1)	—	—	—	—	—	—	1.67	(1)	6.48	(8)	4
50.	*Fabriciana adippe*	5.00	(3)	—	—	5.56	(5)	1.67	(1)	5.00	(3)	5.83	(5)	—	—	15.37	(17)	5
51.	*Speyeria aglaja*	—	—	—	—	2.22	(2)	—	—	—	—	6.67	(4)	3.33	(2)	13.58	(8)	3
52.	*Limenitis camilla*	4.17	(10)	9.44	(17)	16.67	(15)	1.67	(2)	—	—	4.17	(5)	9.44	(14)	25.31	(63)	6
53.	*Limenitis glorifica*	—	—	5.00	(6)	1.11	(1)	—	—	—	—	—	—	—	—	10.19	(7)	2
54.	*Neptis sappho*	7.08	(17)	7.33	(22)	5.83	(5)	2.50	(3)	3.33	(1)	3.33	(6)	4.17	(4)	15.99	(58)	7
55.	*Neptis philyra*	1.67	(1)	3.33	(2)	—	—	—	—	—	—	—	—	—	—	8.33	(3)	2
56.	*Neptis alwina*	1.67	(1)	1.67	(1)	—	—	—	—	—	—	—	—	1.67	(1)	5.56	(3)	3
57.	*Neptis rivularis*	1.67	(1)	—	—	—	—	—	—	—	—	—	—	—	—	5.56	(1)	1
58.	*Neptis pryeri*	4.44	(8)	19.17	(23)	2.22	(2)	—	—	—	—	1.67	(1)	3.33	(4)	20.56	(38)	5
59.	*Araschnia burejana*	1.67	(1)	—	—	—	—	—	—	—	—	—	—	—	—	5.56	(1)	1
60.	*Polygonia c-aureum*	3.33	(8)	5.83	(4)	3.89	(3)	3.33	(1)	—	—	2.50	(2)	10.00	(3)	16.05	(21)	6
61.	*Polygonia c-alubum*	2.50	(2)	—	—	4.17	(3)	—	—	—	—	1.67	(1)	2.50	(2)	9.03	(8)	4
62.	*Kaniska canace*	2.08	(5)	3.33	(2)	—	—	—	—	—	—	2.50	(2)	5.00	(3)	10.76	(12)	4
63.	*Nymphalis xanthomelas*	—	—	—	—	—	—	—	—	—	—	2.50	(2)	1.67	(1)	6.94	(3)	2
64.	*Inachis io*	—	—	—	—	1.67	(1)	—	—	—	—	—	—	—	—	5.56	(1)	1
65.	*Dichorragia nesimachus*	1.67	(1)	3.33	(2)	—	—	1.67	(1)	—	—	—	—	—	—	7.41	(4)	3
66.	*Apatura metis*	1.67	(2)	3.33	(2)	—	—	—	—	—	—	—	—	3.33	(1)	9.26	(5)	3
67.	*Hestina persimilis*	1.67	(1)	—	—	—	—	—	—	—	—	—	—	—	—	5.56	(1)	1
68.	*Sasakia charonda*	—	—	6.67	(4)	—	—	—	—	—	—	—	—	—	—	22.22	(4)	1
	Satyridae																	
69.	*Ypthima argus*	3.33	(6)	3.89	(7)	4.07	(10)	3.33	(2)	—	—	7.22	(9)	6.67	(8)	15.84	(42)	6
70.	*Minois dryas*	11.11	(20)	20.00	(24)	—	—	9.17	(11)	—	—	25.00	(28)	7.50	(8)	48.52	(91)	5
71.	*Lethe diana*	1.67	(1)	—	—	—	—	—	—	—	—	—	—	—	—	5.56	(1)	1
72.	*Mycalesis gotama*	1.67	(1)	—	—	—	—	—	—	—	—	—	—	—	—	5.56	(1)	1
	Total	208.92	(314)	252.22	(307)	145.28	(163)	85.06	(75)	44.17	(22)	196.46	(221)	185.14	(172)	968.23	(127.4)	

*: This value was calculated by averaging the population abundances of each butterfly species at only sites where the species was recorded, and converting this value into that per 1 km.

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